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Status of Water Quality in Mt. Elgon, Cherangany Forested Ecosystems and entire River Nzoia Catchment in Kenya

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Abstract: Water availability for both domestic and industrial use is a major growing problem in the developing countries including Kenya. The situation is further worsened by increasing human population and climate change, probably the most complex environmental problem facing the world today. Mt. Elgon and Cherangany hills forest ecosystems in the River Nzoia Catchment are threatened by the increase in local population. This is causing environmental degradation and disruption in the catchment areas resulting in drying up of streams and rivers and both water and soil pollution. The objective of this study was to conduct a baseline survey to provide information on the status of water quality in the River Nzoia Catchment and an overview of pollution levels, sources and possible mitigation measures. The study was carried out in August 2017 during the short rains. Water and sediments from 26 spatially distributed sites on rivers in the catchment were sampled and analyzed. The water quality (physical and chemical) was assessed through analysis of water and sediments. Both water and sediments were analyzed following the standard analytical methods. All the rivers in the watersheds forming the River Nzoia catchment contained high levels of iron in water which exceeded permitted levels for drinking without treatment and for domestic uses in the environmental. In addition, the turbidity levels of water were beyond accepted limits set for drinking water and environmental water standards. There was little pollution of water from heavy metals. River Nzoia near Webuye town and Sigomre bridge were the most polluted waters with levels of nitrates, iron, copper, chromium, with BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand) exceeding the accepted limits in the environment. For sediments, the contents of copper, magnesium and iron were high in the upper catchment of River Nzoia (foot slopes of Mt. Elgon). The levels of nitrates and phosphates in the sediments were high in the lower parts of the catchment. The recommended interventions to manage point or non-point pollution sources include: land and soil conservation to reduce erosion, precision in fertilizer usage, proper sewage and industrial effluent treatment and disposal. The mitigation measures should be at the sub-catchment level to reduce land, soil and water pollution. Technologies for soil and water conservation including afforestation on bare lands, control of overland flow, reduction on river bank cultivation and conservation agriculture practices will reduce pollution and conserve the environment.

Key words: Catchment, ecosystem, environment, quality, sediments, soil, water, watershed.

1. Introduction

Mt. Elgon and Cherangany hills forest ecosystems are part of the Kenya's water towers and are the major sources of rivers draining into Lakes Victoria and Turkana [1, 2]. These ecosystems also recharge ground-water aquifers, reduce soil erosion into rivers and regulate local climatic conditions as well act as carbon reservoirs and sinks [2]. The two forested ecosystems are threatened by human population pressure causing land, soil and water degradation in the catchment area [1, 3].

The degradation of land, soil and water has led to drying up of rivers, pollution and reduction in water bodies' levels in the River Nzoia catchment. Deforestation of these water towers as a result of human settlement and agriculture has increased surface runoff leading to soil erosion. The eroded soils cause siltation of water bodies reducing discharge volumes and causing floods. For instance, flooding is a perennial problem in the lower River Nzoia which sometimes

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causes loss of lives and property destruction [4]. Water pollution in the River Nzoia catchment is from both point and non-point sources which are mostly anthropogenic [5, 6]. High levels of phosphates, nitrates and banned compounds such as aldrin, dieldrin and DDT (Dichlorodiphenyltrichloroethane) in water have been reported in River Nzoia Basin which has been attributed mainly to agricultural activities [6]. Furthermore, nutrients mostly nitrates, phosphates, TOC (Total Organic Carbon) among others from surface runoff are a major cause for eutrophication in Lake Victoria resulting in massive algae blooms, water hyacinth infestation and oxygen depletion in water [5, 7, 8].

Water quality assessment evaluates the physical, chemical and biological nature of water in relation to natural quality, human effects and intended uses [9-11]. In Kenya, the Environmental Management and Coordination, (Water Quality) Regulations 2006 of the Environmental Act of 1999, outlines the permitted levels of water quality parameters for different uses [12]. In addition, the Water Services Regulatory Board (Wasreb) in Kenya [13] is in charge with the responsibility of regulating and setting standards for water service providers [14]. Globally, the World Health Organization [9] and United States Environmental Protection Agency [15] among others have developed the criteria and standards for water quality monitoring. The changes in the physical and chemical parameters of water affect water quality and they mainly include: pH, dissolved oxygen, BOD (Biological Oxygen Demand), COD (Chemical Oxygen Demand), turbidity, phosphates, nitrates, electrical conductivity, and heavy metals among others. The pH of river water is vital to aquatic life and affects the ability of aquatic organisms to regulate basic life-sustaining processes. Alkalinity is a measure of all the substances in water that can resist a change in pH when acid is added to the water while turbidity is a measure of dissolved coloring compounds in water and can be attributed to presence of organic and inorganic materials [15]. The suspended solids in water are closely linked to erosion and nutrient transport, industrial waste and chemicals used in agriculture. Nitrogen is of great importance to the quality of water in rivers, and as a nutrient in water may cause eutrophication. Nitrite which is an intermediate in oxidation of ammonia, is toxic to aquatic life and is commonly found in sewage effluents which are rich in ammonia. The BOD measures biologically oxidized pollutants while COD measures the chemically oxidized ones in water. BOD is mostly associated with wastewater from sewage systems while COD associated with industrial effluents. In the River Nzoia basin, the dissolved oxygen and BOD have been found to fluctuate with rainfall patterns which affect the discharge volumes [16]. The purpose of this study was to provide information on the water quality status in the catchment area and give an overview of the pollution levels, interventions and the mitigation measures.

The water quality was assessed through analysis of water and sediments for physical and chemical parameters. The study process was aided by the use of the GIS (Geographical Information Systems) and the SDSS (Spatial Decision Support Systems) in remote sensing in mapping the catchment. The study was carried out in August 2017 during the short rains.

2. Materials and Methods

2.1 Study Area: Mt. Elgon and Cherangany Forest Ecosystems/River Nzoia Catchment

Mt. Elgon forest ecosystem forms the upper catchment area for three major rivers: Nzoia, Malakisi and Sio which drain into Lake Victoria and transverse through Bungoma, Trans Nzoia, Kisumu, Siaya and Busia counties. The Cherangany hills forest ecosystem and streams in west of the Cherangany hills watershed feed the Nzoia River system. The River Kapolet originating from Kapolet Forest in Elgeyo Marakwet County is a tributary and source of river Nzoia and provides water consumed in Trans Nzoia and

Bungoma Counties. The specific spatial distribution of sampling sites on rivers for water quality is shown in Table 1 and Fig. 1.

2.2 Mapping of the River Nzoia Catchment Using GIS

In mapping water quality within River Nzoia Catchment, two methods of spatial data acquisition were employed. The first approach involved ground based method—where all sampling stations were mapped and predetermined water quality parameters recorded, the second approach was the use of remote sensing where ASTER (Advanced Space-Borne Thermal Emission and Reflection Radiometer) Global Digital Elevation Model Version 2 was used to delineate river channels at 30 meters spatial resolution and the sub-catchments contributing area. The integration of the approaches was made possible on GIS platform using ArcGIS 10.5.

2.3 Assessment of Water Quality (Laboratory Protocols/Methods)

The water quality was assessed through analysis of water and sediments. The sampling activity was done in August 2017 during the short rains.

For water sampling, samples were taken in the surface water layer (0-5 cm from the surface) at the center of the main flow. The sediment samples came from three equidistant positions within a 50 m radius i.e. at the either sides of the river banks. The water samples were taken by plunging the bottle underneath the surface and water collected facing upstream direction. Some of the sampling protocols were adapted from Refs. [14, 17]. The PTFE (Polytetrafluoroethylene) bottles were used to transport and store the samples

Table 1 Spatial distribution of sampling sites in the River Nzoia catchment.

Name of river	GPS coordinates	
1. River Chepkaitit near Kapcherop town bridge	35°20'01.5"E	1°02'18.1"N
2. River Seum at Mito mbili bridge	35°14'09.1"E	0°59'16.7"N
3. River Chepkaitit at chepkaitit bridge	35°14'21.7"E	0°56'59.1"N
4. River Kapterit at Mwaita bridge	35°11'58.7"E	1°01'46.7"N
5. River Nzoia at Kapolet North water treatment site	35°09'51.4"E	1°07'59.2"N
6. River Nzoia at Kapolet bridge	35°09'18.0"E	1°08'30.0"N
7. River Koitobos (Koitobos bridge)	35°04'12.0"E	1°01'23.1"N
8. River Nzoia at Moiben bridge	35°07'56.4"E	0°55'31.6"N
9. River Moiben at Moiben bridge	35°07'57.6"E	0°55'06.9"N
10. River Kiptogot near Chepchoina centre	34°49'45.5"E	1°08'47.6"N
11. River Mubere at Mubere bridge	34°50'22.9"E	1°06'58.4"N
12. River Kaibei/Koitobos	34°50'28.8"E	1°06'39.7"N
13. River Sabwani at Endebess bridge	34°51'18.7"E	1°04'57.7"N
14. River Nzoia at Moi'sbridge Town bridge	35°07'01.4"E	0°52'60.0"N
15. River Sosian downstream at Kamagut bridge	35°10'48.3"E	0°33'06.4"N
16. River Sosian Eldoret downtown bridge	35°17'07.6"E	0°30'22.9"N
17. River Kipkaren at Kipkaren Town bridge	34°57'53.5"E	0°36'24.0"N
18. River Nzoia at Brigadier bridge in Soysambu	35°03'46.8"E	0°45'38.1"N
19. River Kiminin at Kiminin bridge	34°55'37.5"E	0°46'17.9"N
20. River Nzoia at Webuye bridge	34°48'24.8"E	0°35'09.8"N
21. River Kuywa at L.Victoria Basin water treatment site	34°41'59.5"E	0°37'12.9"N
22. River Nzoia at Mumias bridge	34°29'12.8"E	0°22'09.6"N
23. River Lusumu at Mumias-Musanda Road Bridge	34°28'45.6"E	0°18'22.5"N
24. River Nzoia bridge at Sigomre/Sigomere bridge	34°20'28.9"E	0°14'56.8"N
25. River Nzoia at Ruambwa bridge	34°05'35.9"E	0°07'02.7"N

World Geodetic System WGS84 Datum, zone 36N.

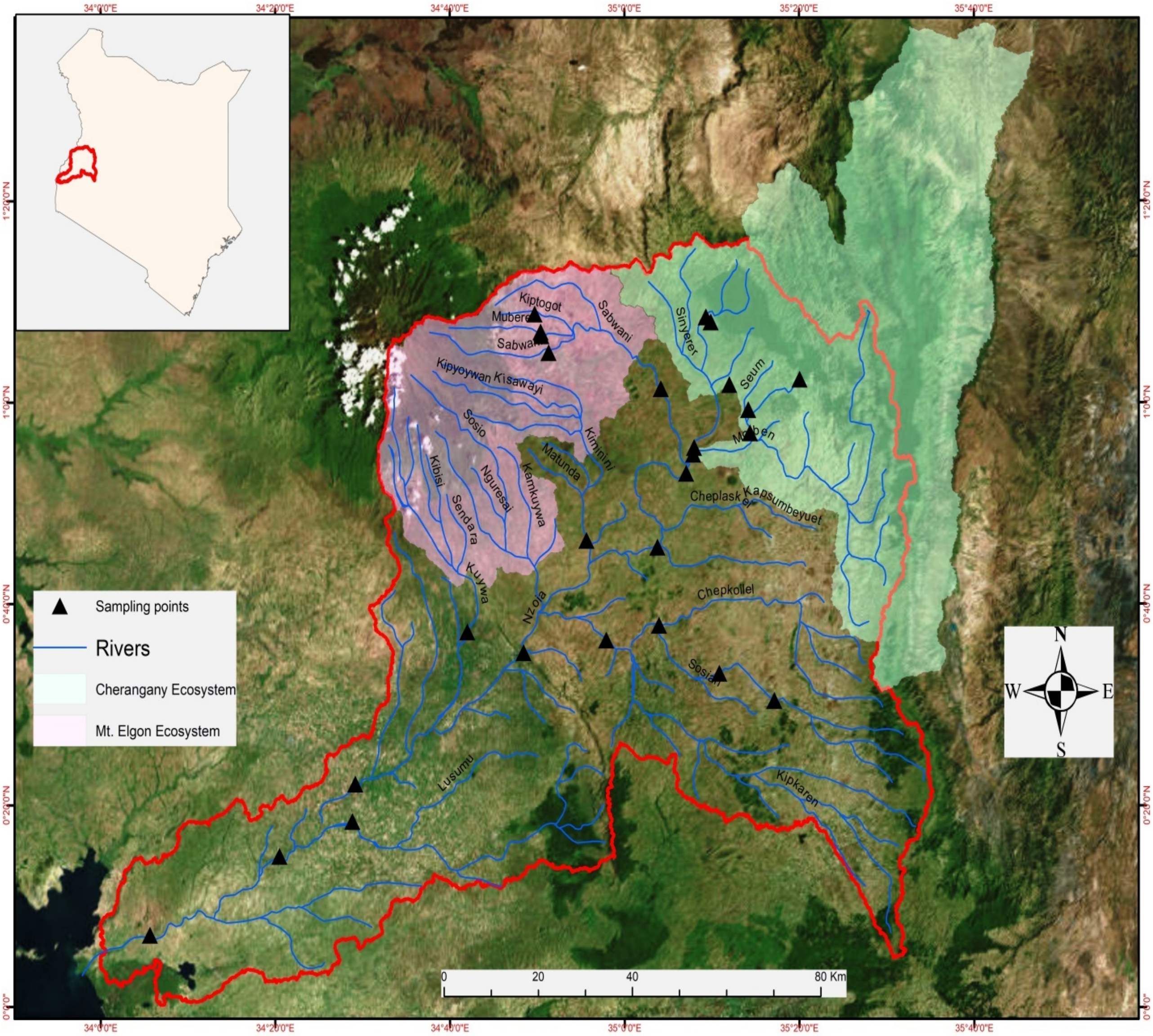

Fig. 1 Spatial distribution of the sampling sites in the River Nzoia catchment.

after sterilization and rinsing with deionized water. Sediments were taken at exact or near water sample points because the sediment sampling was linked to a water quality study.

Both physical (turbidity, TSS (Total Suspended Solids), TDS (Total Dissolved Solids), pH etc.) and chemical parameters (nitrates, nitrites, phosphates, COD, BOD and heavy metals) of water were analyzed while chemical parameters were only for sediments. Both water and sediments were analyzed following the analytical standard methods. The contents of nitrate, nitrite, phosphate, zinc, iron, copper, chromium, hardness and alkalinity were measured spectrophotometrically.

Turbidity, TDS, pH, conductivity and temperature were measured potentiometrically. TSS was measured by gravimetric method. COD was measured using reactor digestion method while BOD was measured respirometrically. The coliform bacteria were measured by membrane filtration, lead measured using ISO 8288, cadmium (ISO 5961), arsenic (ISO 11969) and mercury measured using USEPA-245 protocols. For sediments, nitrates and phosphates were determined spectrophotometrically. The TOC was determined by both Loss on Ignition and titration methods. Zinc, iron, copper and magnesium were determined using atomic absorption spectrophotometry. The pH and conductivity were measured by potentiometric method. Turbidity, temperature, pH and electrical conductivity were measured onsite in the field during sampling.

3. Results and Discussion

3.1 Nitrates and Nitrites

In this study, river Nzoia at Webuye Bridge recorded the highest nitrate levels of 13.3 mg/L against acceptable limit of 10 mg/L [18]. Similarly, high levels of nitrites of 0.099 mg/L against acceptable limits of 3 mg/L [18] for domestic water sources were recorded at the same site. The highest nitrite levels of (0.167 mg/L) were recorded at Sosiani river downstream at Kamagut bridge. The nitrate levels of rivers Chepkaitet (Chepkaitet bridge), Koitobos (Koitobos bridge), Sosian at Kamagut bridge and Kipkaren at Kipkaren bridge (6.3, 5.4, 5.1 and 5.1 mg/L) were below the acceptable limits of 10 mg/L but required close monitoring as their levels were relatively high (Figs. 1-5). In addition, the levels of both nitrates and nitrites recorded were above the acceptable limits of 1.0 mg/L and 0.003 mg/L respectively as per the KEBS (Kenya Bureau of Standards) of 2014 for natural portable waters for drinking before treatment.

The high levels of nitrates and nitrites were attributed to pollution from the nearby town industries and agricultural activities in the region. The high levels of nitrate in the river Nzoia catchment have been associated with water hyacinth and algae blooms in the Lake Victoria adversely affecting fish and other aquatic animals.

According to the USEPA (United States Environmental Protection Agency) [15], consumption of water by humans containing high levels of nitrate in excess of 10 mg/L could lead to adverse health effects such as methemoglobinemia ("blue baby" syndrome). Nitrate and nitrite levels in both water and sediment had similar trends in selected sites, notably Sosiani River, whereby the high levels in water correlated with the sediment levels. In addition, the farming activities around the sampled areas could also have contributed to the nitrate levels in sediments. The undetected levels of nitrate in sediments in some sites were largely attributed to high solubility of nitrates in water (Fig. 3).

3.2 Phosphorus/Phosphate

Phosphate concentrations recorded from the rivers in the catchment were significantly low except for rivers Sabwani, Sosian and Kiminini recording concentrations of 2.56 mg/L, 2.49 mg/L and 41.5 mg/L respectively against acceptable limit of 2.2 mg/L [19] for natural portable water for drinking as shown in Fig. 6. In Kenya, there are no set standards for phosphate content in natural water sources/supplies. These high phosphate concentrations were mainly attributed to surface runoffs from farming activities and livestock waste in the surrounding areas. For river Sosiani, the high levels of phosphates were attributed to municipal wastes from Eldoret town. With this high level of phosphates, there was likely to be eutrophication downstream (lower catchment) of River Nzoia resulting in problems like excessive growth of water hyacinth as witnessed at Ruambwa and Sigomre sites along River Nzoia. In addition, this eutrophication also depletes dissolved oxygen levels in water which is detrimental to aquatic life.

The amount of phosphorus present in a water body depends on both the external phosphorus load and its release and retention in the sediments. Sediments act as a sink where phosphorus can be stored, and as a source of phosphorus for the overlying river water. In this study, total phosphorus concentrations in sediments varied considerably ranging from 29 ppm to 619 ppm. The lowest concentrations of 29 ppm recorded were at River Nzoia at Kapolet North water treatment site which is the source of River Nzoia in the Cherangany forested hills which was less polluted. High concentrations recorded at rivers Chepkaitet, Seum,

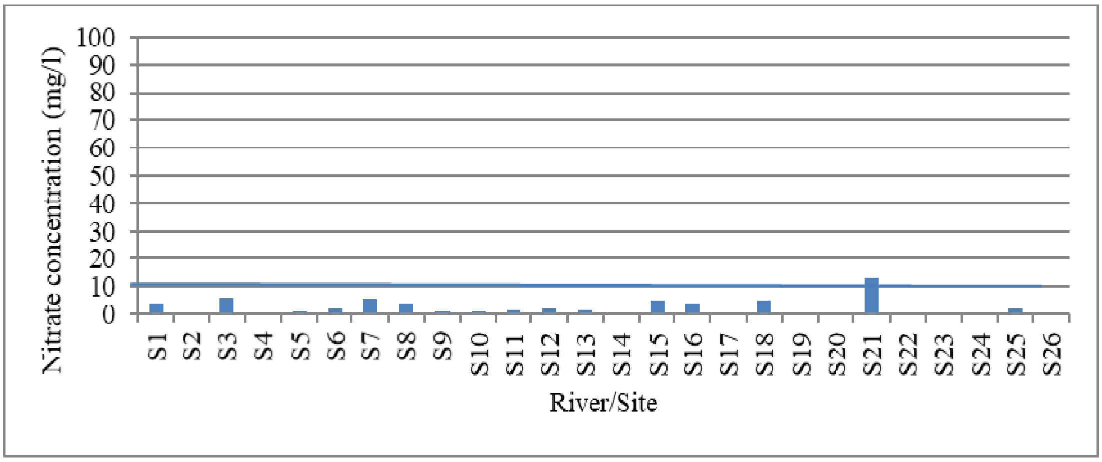

Fig. 2 Nitrate levels in water.

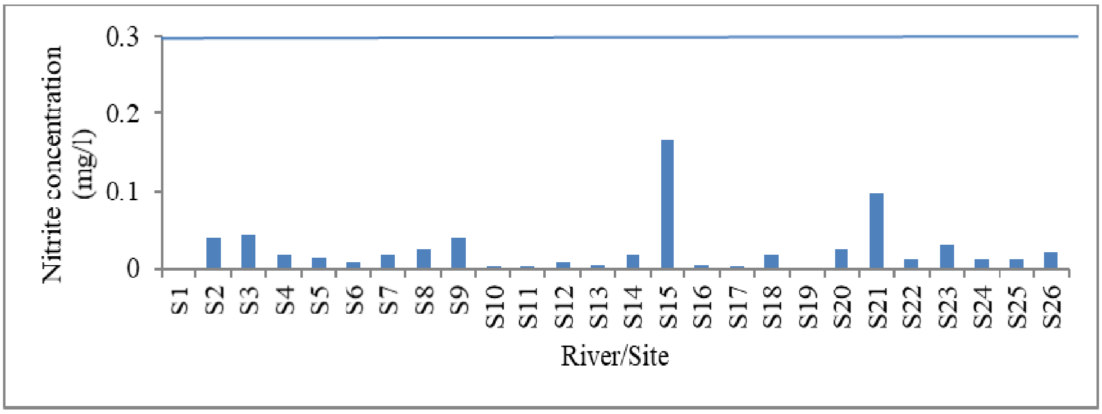

Fig. 3 Nitrite levels in water.

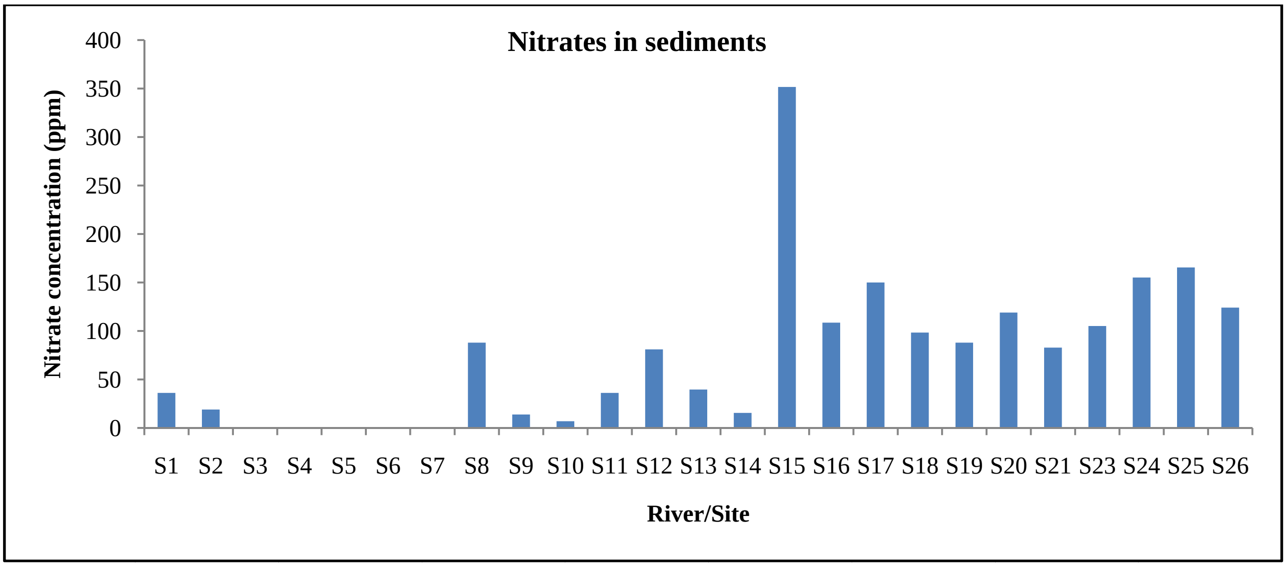

Fig. 4 Nitrates in river sediments.

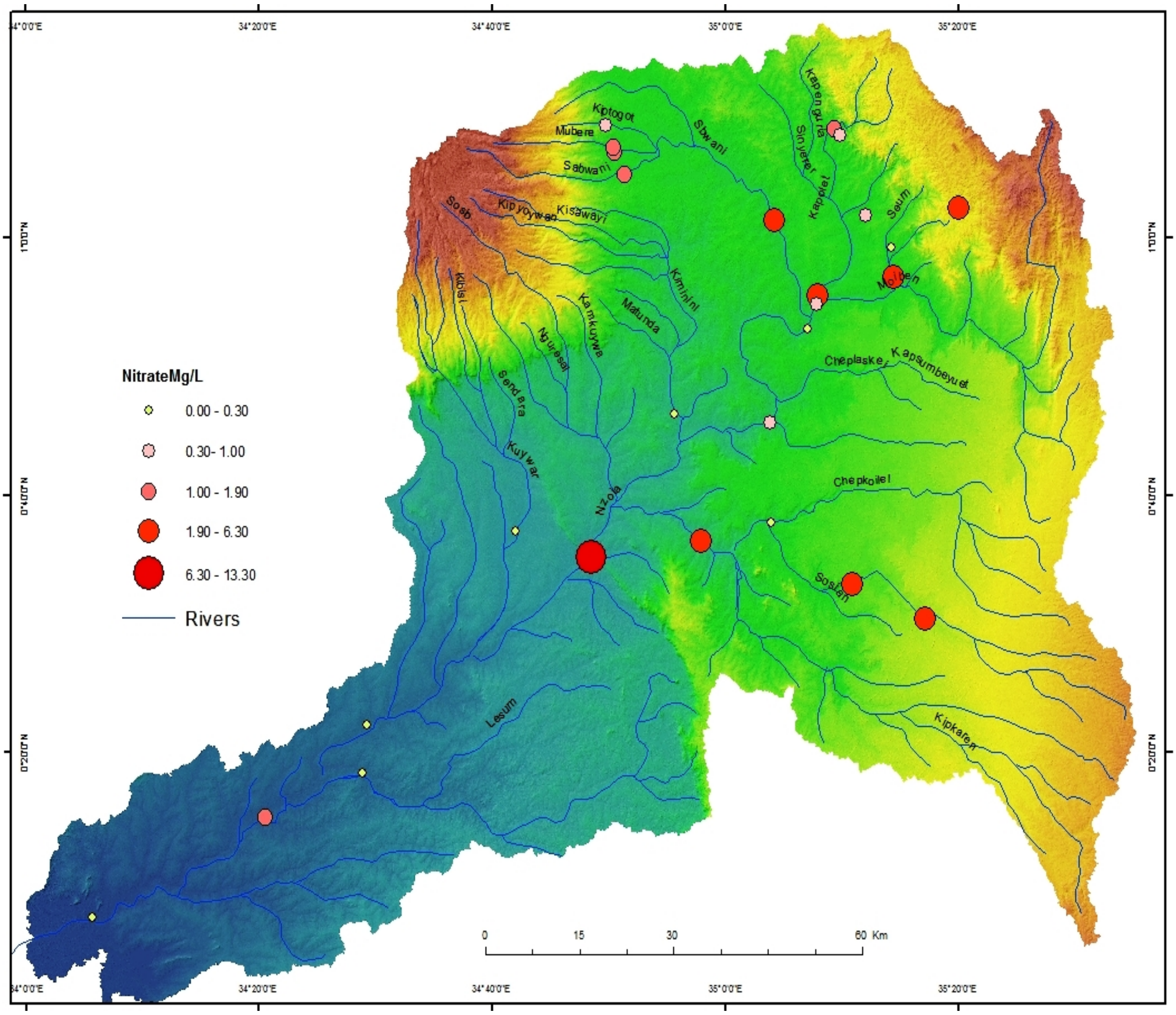

Fig. 5 Pollution map for nitrate levels in water.

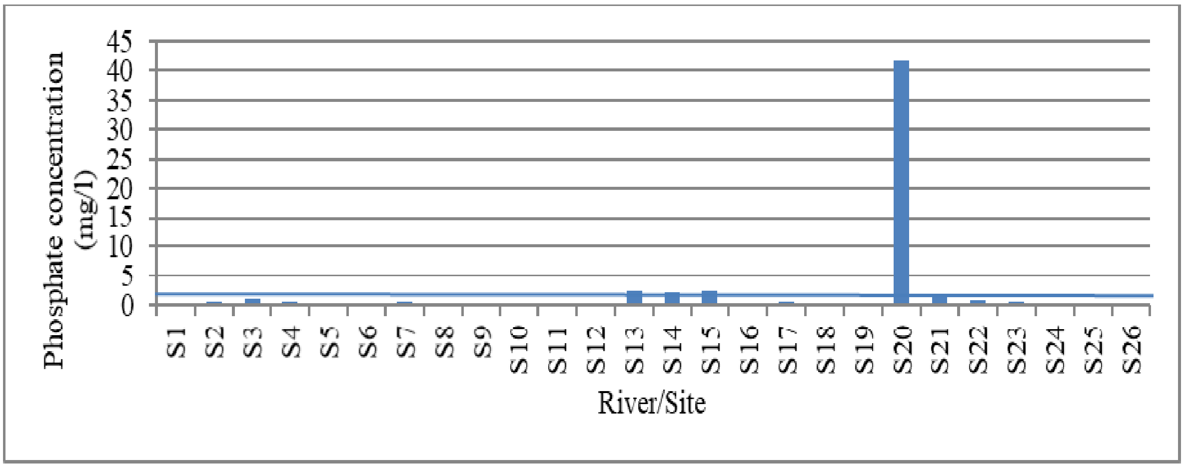

Fig. 6 Phosphates levels in water.

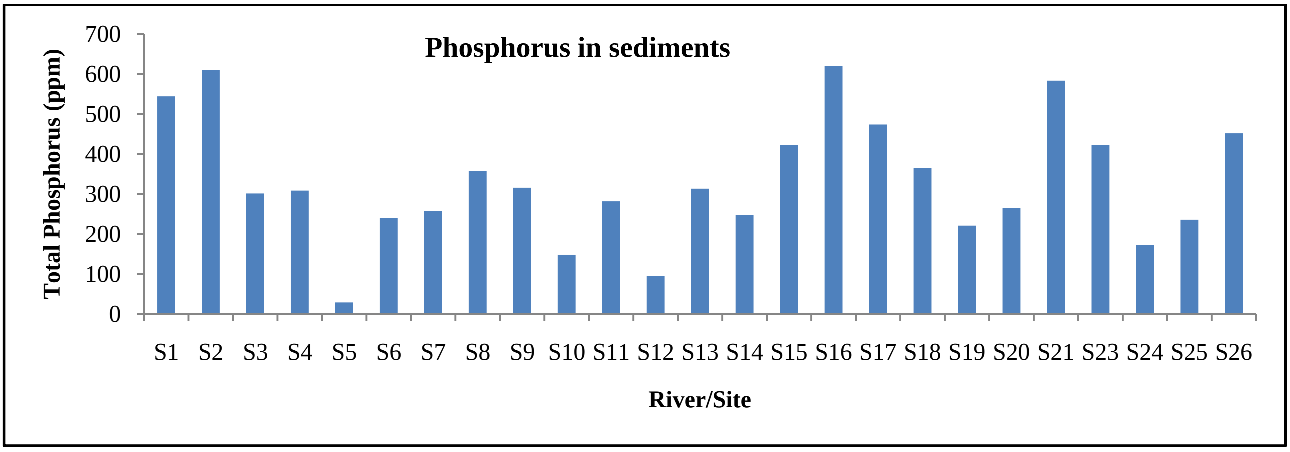

Fig. 7 Total phosphorous in sediments.

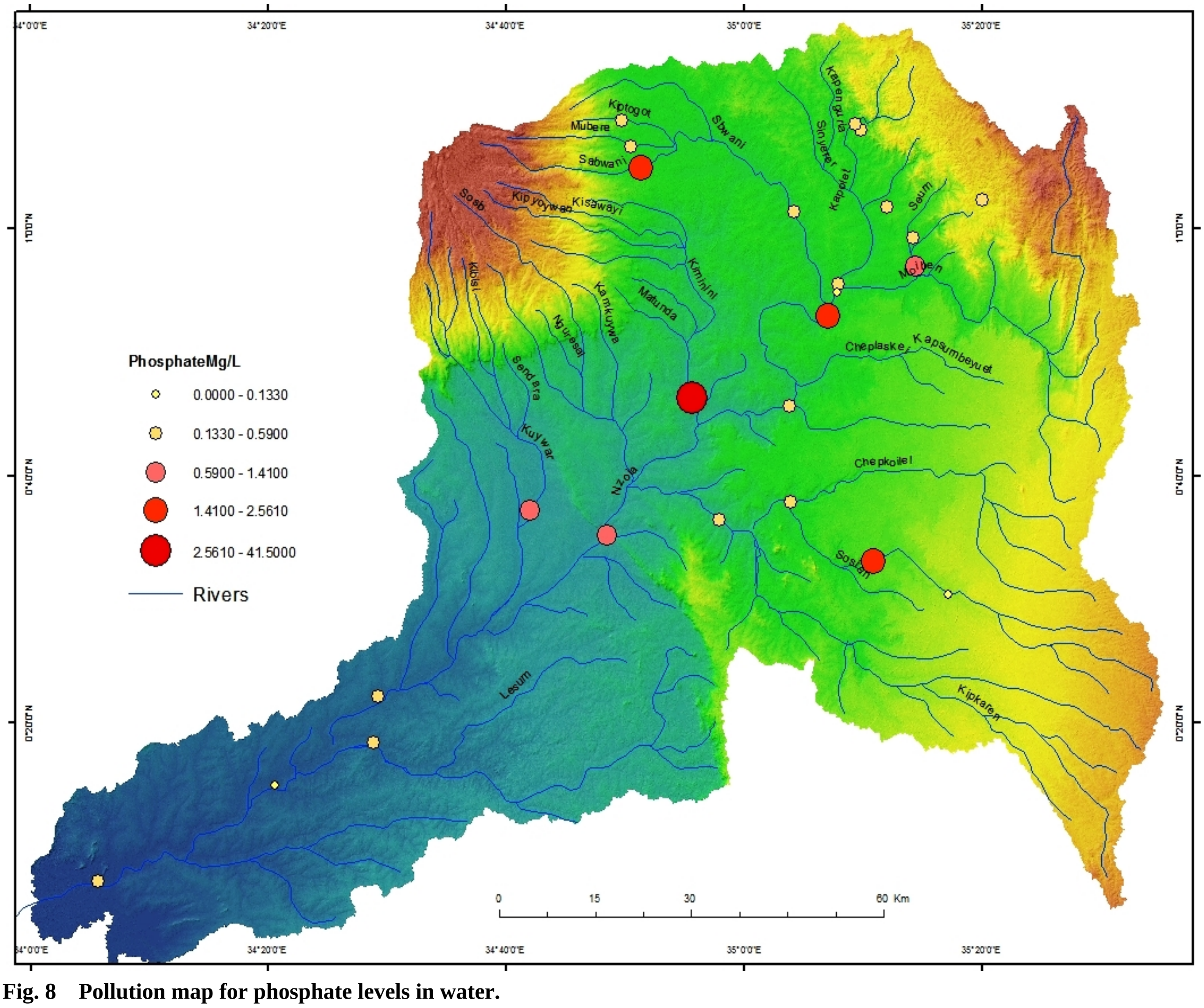

Fig. 8 Pollution map for phosphate levels in water.

Sosian and Nzoia at Webuye town of 544 ppm, 609 ppm, 619 ppm and 583 ppm respectively (Figs. 7 & 8) were associated with erosion from run-offs, non-point sources of pollution such as municipal waste, waste water, sewerage and farming activities; and point-source pollution from industries around Webuye town.

3.3 Turbidity

In this study, the turbidity levels of the sampled rivers were high (45-700 NTUs) and beyond acceptable limits set for natural portable drinking water in the environment in Kenya (KEBS, 2014) i.e. 25 NTUs and therefore requires timely interventions. These high levels were attributed to seasonal weather variations and land use activities at the time of sampling whereby, it was in a rainy season with high rates of soil being eroded into rivers through surface runoff. Furthermore, high turbidity was also synonymous with big rivers perhaps due to high sediment load as a result of high discharge volumes as witnessed both in the upper and lower catchment areas of river Nzoia near the mouth of Lake Victoria (Figs. 9 and 10). For instance, River Nzoia at Kapolet Bridge (471 NTUs), River Koitobos at Koitobos Bridge (597 NTUs), and the larger River Nzoia at Moi'sbridge Bridge (427 NTUs), Sigomre and Ruambwa bridge (664 NTUs), are big rivers which were very turbid (Fig. 9). In Kenya, there are no set standards for turbidity levels in natural water sources/supplies in the environment. Low clarity levels in water reduce sunlight absorption causing high temperatures which in turn lower oxygen levels. This is detrimental to aquatic life as photosynthesis is also affected due to reduced light penetration.

3.4 Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

In this study, both BOD and COD levels had similar trends in the sampled sites with nearly all the sampled sites/rivers being within the acceptable limits in the environment. River Chepkaitet at Chepkaitet bridge, river Koitobos at Koitobos bridge and the larger river Nzoia near Webuye town had levels above the threshold value of 30 mg/L (BOD) and 50 mg/L (COD) permitted in the environment as effluent discharge [18] as shown in Figs. 11-14. High BOD/COD levels in River Nzoia near Webuye town were attributed to industrial effluents from industries around the town and sewage treatment plants. For Koitobos and Chepkaitet sites, organic materials from highly fertilized farms and use of pesticides especially flower and cereal maize farms in the area were the most likely causes of the high BOD/COD levels (Figs. 11-14). In river water quality, BOD is mostly associated with wastewater from sewage systems while COD associated with industrial effluents.

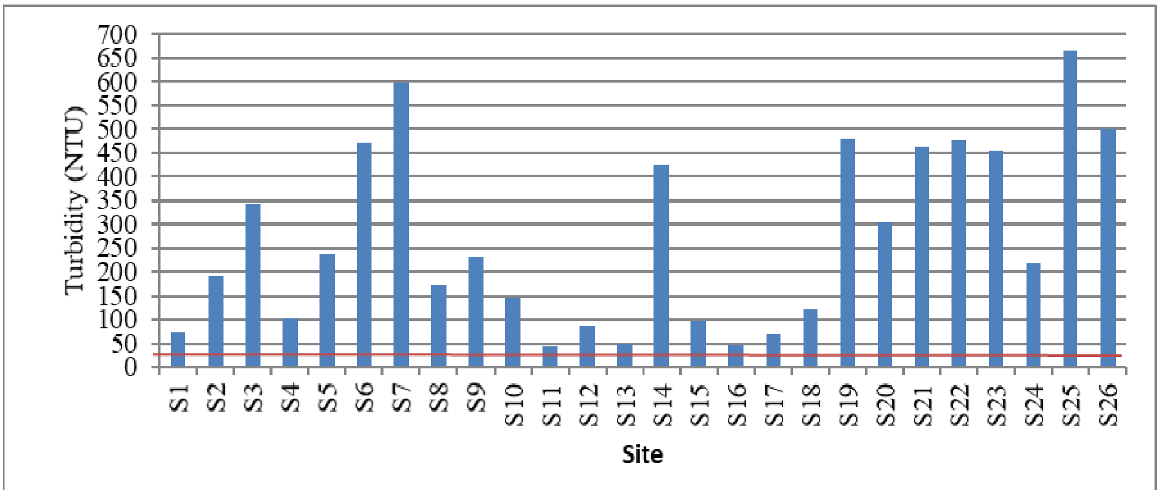

Fig. 9 Turbidity levels of water.

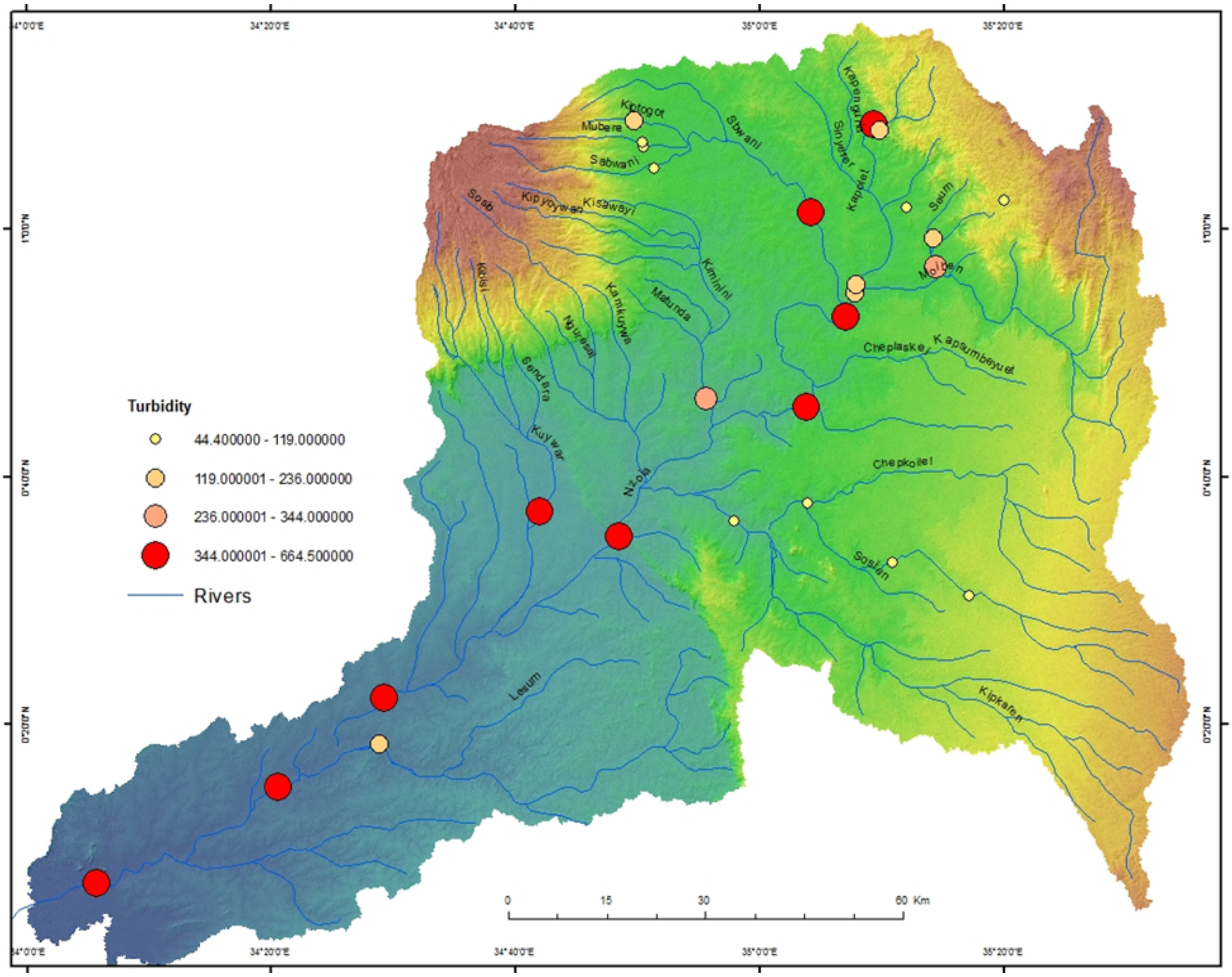

Fig. 10 **Pollution map for Turbidity levels in water.**

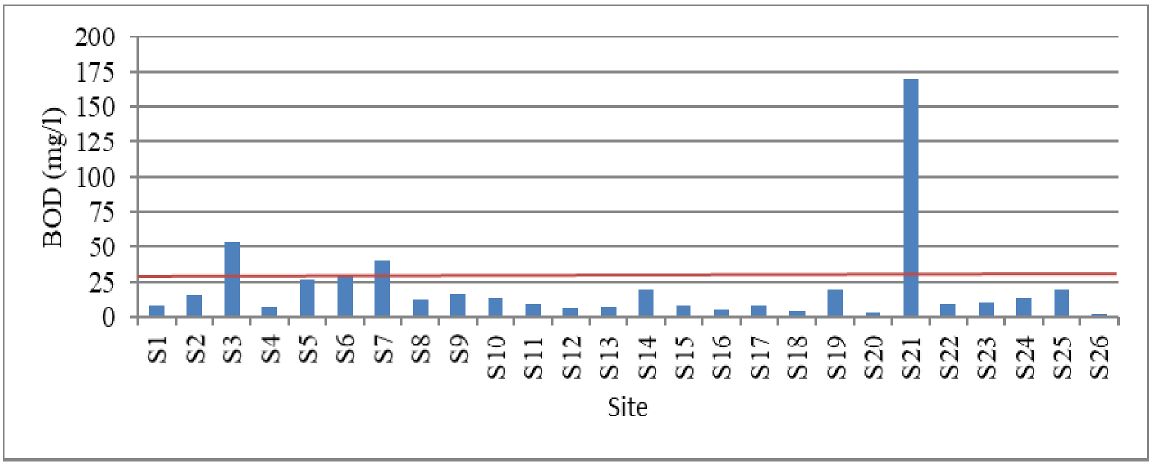

Fig. 11 **BOD of water.**

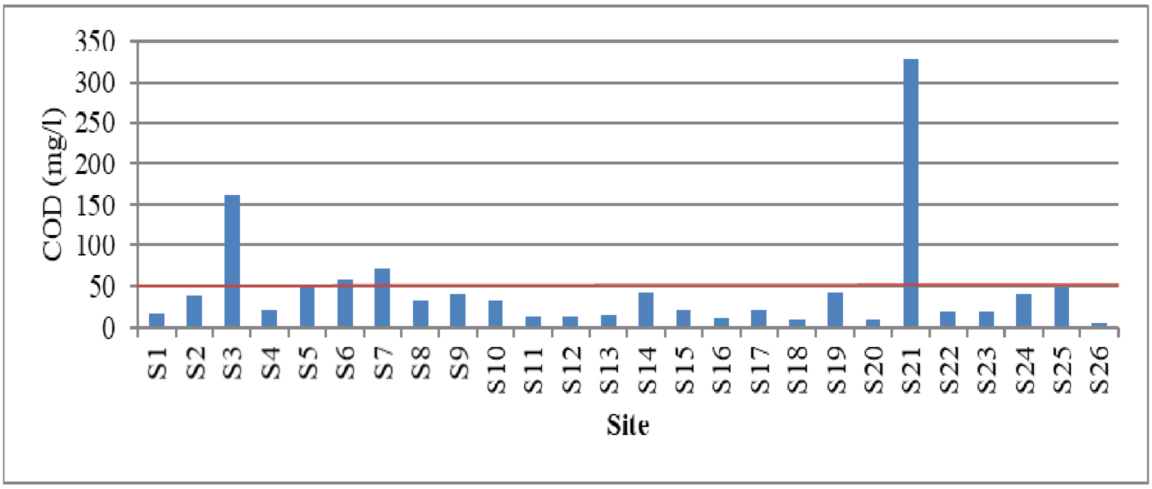

Fig. 12 COD of water.

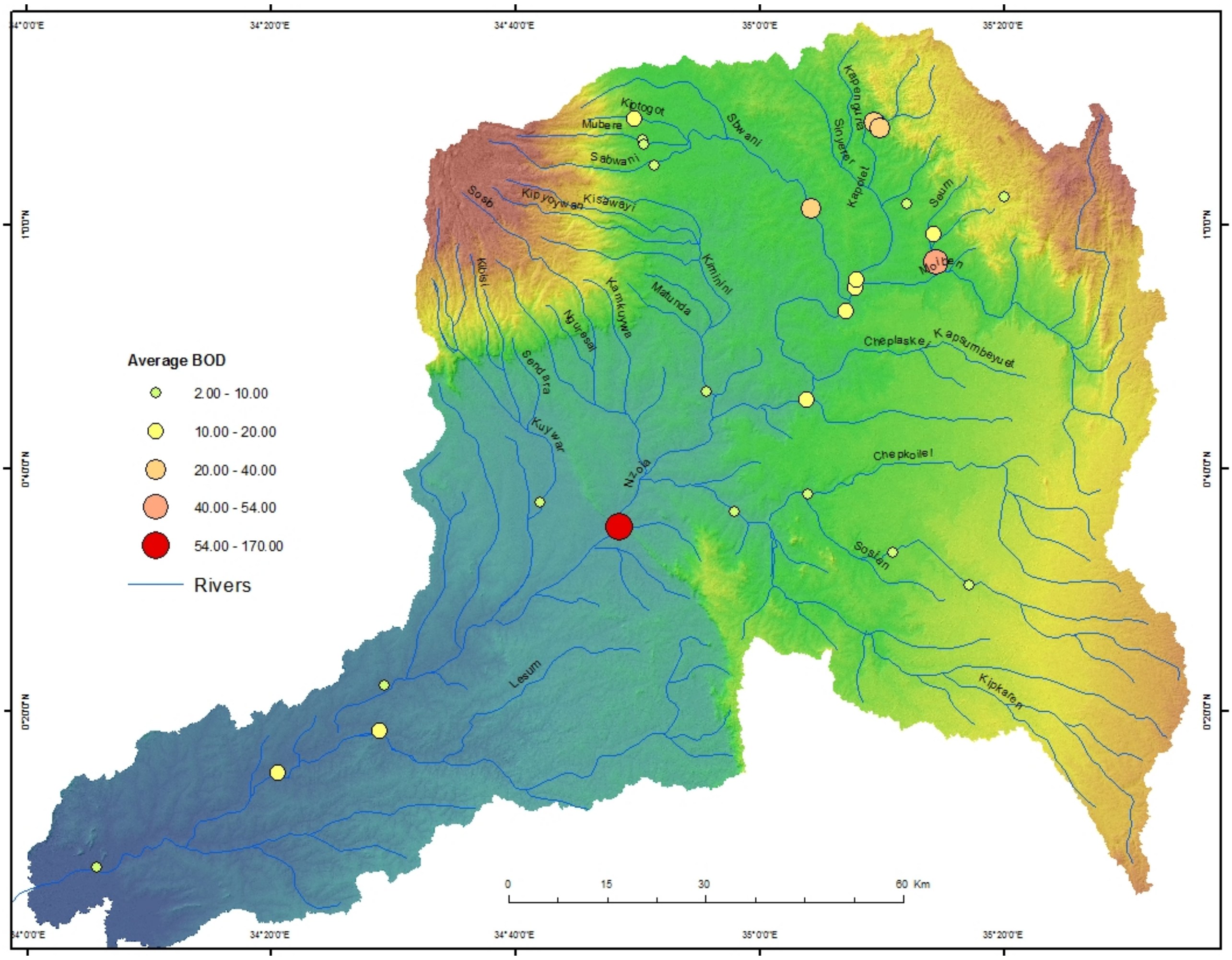

Fig. 13 Pollution map for BOD.

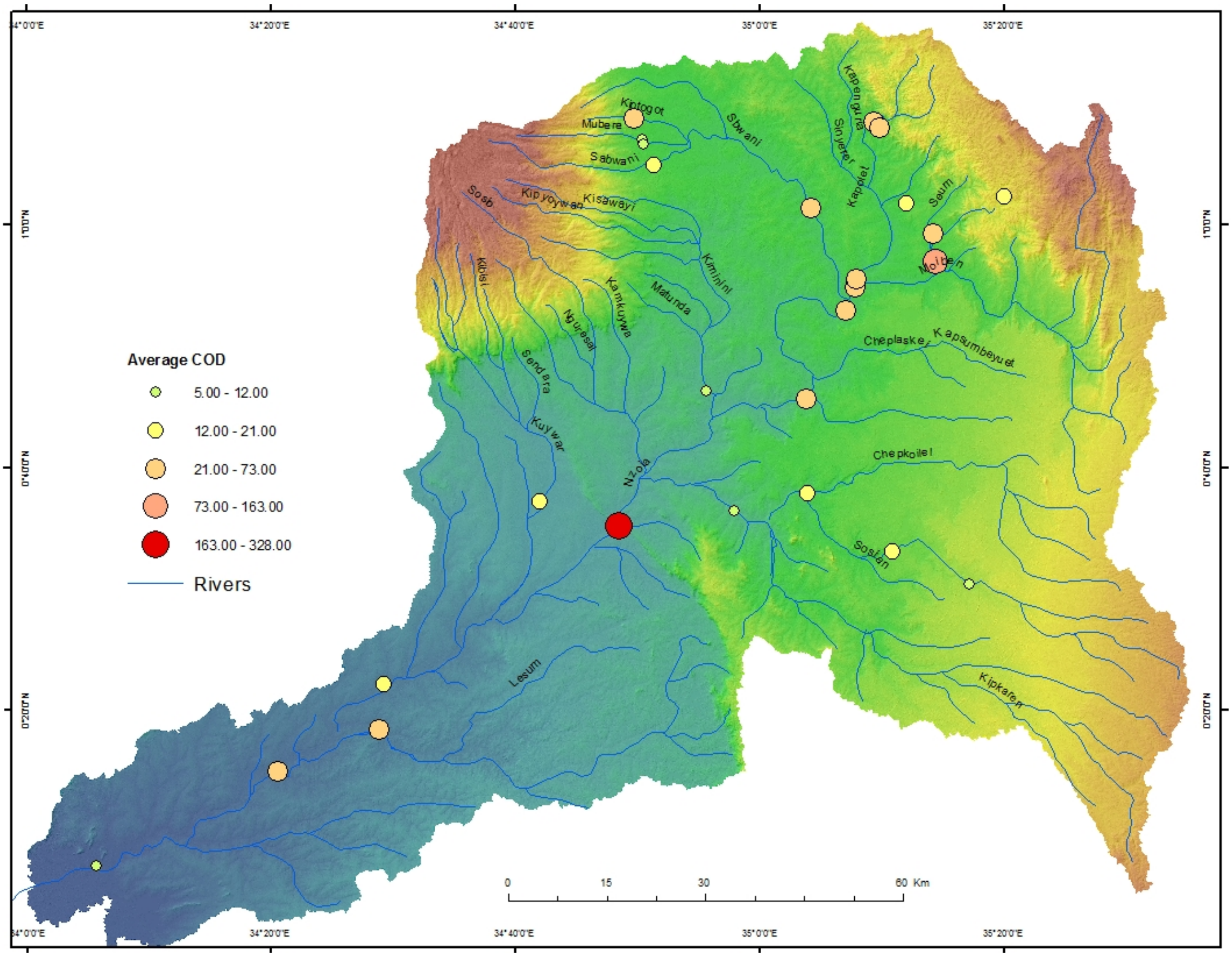

Fig. 14 Pollution map for COD.

To reduce or manage high BOD/COD values, proper design of waste water and sewage treatment plants should be done especially aeration. Therefore, the waste water effluent and sewage discharges should be monitored in the affected areas as a way of reducing point source pollution in the rivers.

3.5 Chromium

High levels of chromium in the catchment were recorded near Webuye town (0.29 mg/L) on River Nzoia and at Kipkaren Town Bridge (0.073 mg/L) on River Kipkaren against maximum acceptable limits of 0.05 mg/L [19] for natural portable waters as shown in Fig. 15. This was attributed to point pollution by industries around Webuye town. For irrigation purposes, the river waters in the catchment are suitable for irrigation as the chromium levels were below the Kenyan standards of 1.5 mg/L [18]. At Kipkaren Bridge, the river runs through the middle of the township where all kinds of wastes are dumped into the river. The chromium in water could end up being consumed by fish and enter the food chain. When consumed by humans, chromium poses health risks including carcinogenic effects and kidney damage.

3.6 Iron and Copper

The majority of the rivers in the Catchment had iron levels exceeding the allowable limits of 1 mg/L for irrigation waters [18] and 0.3 mg/L [19] for natural portable waters. River Kuywa water treatment site near Bungoma town and River Nzoia at Sigomre

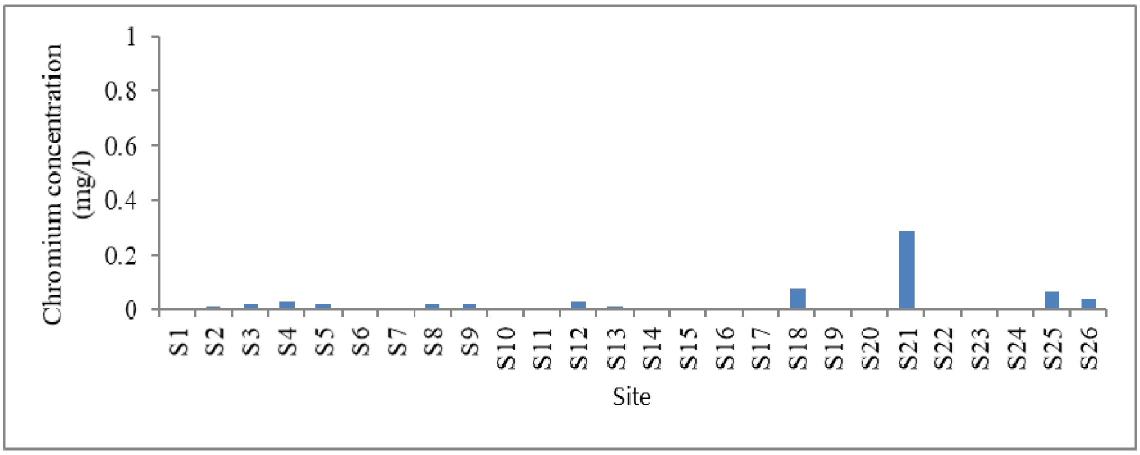

Fig. 15 **Chromium concentrations in water.**

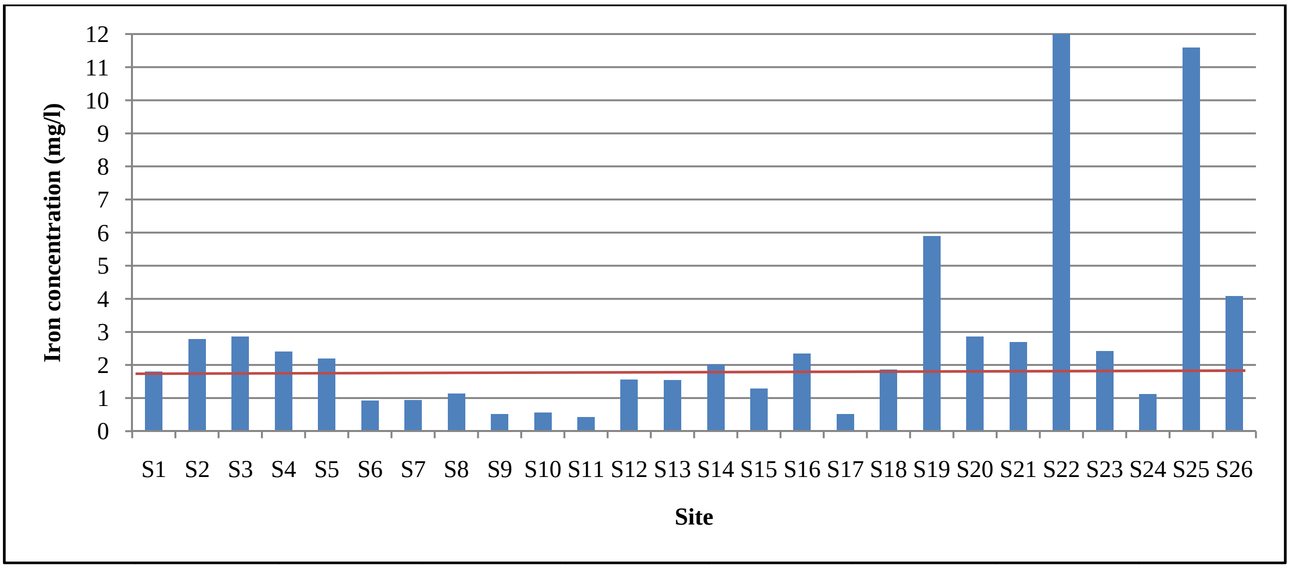

Fig. 16 **Iron concentration in water.**

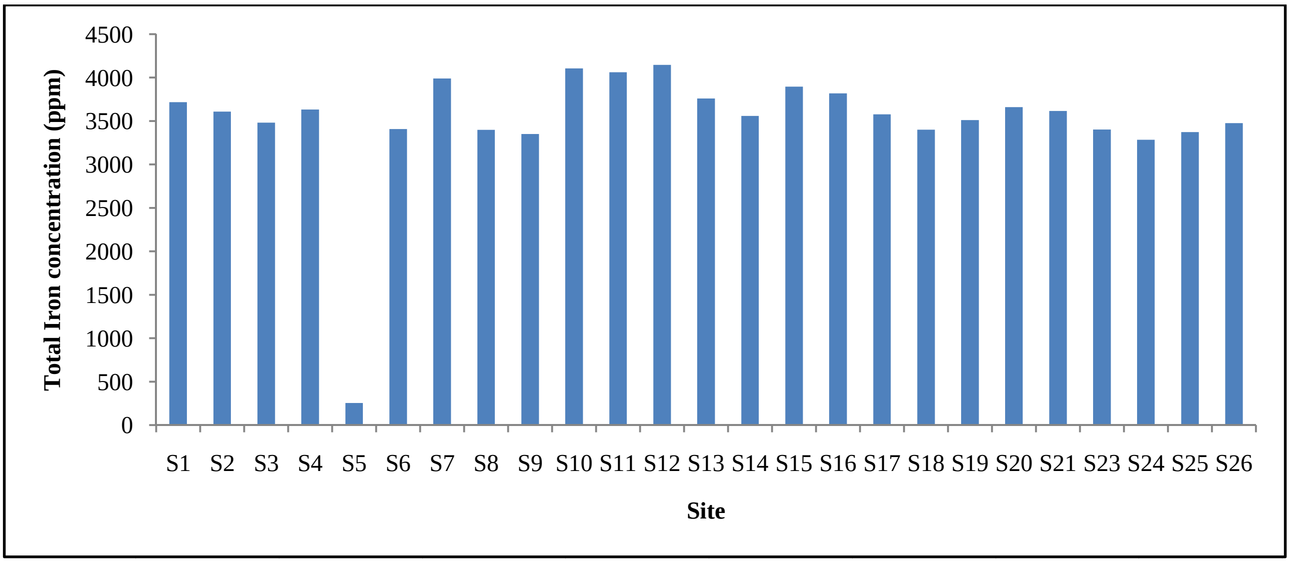

Fig. 17 **Total iron concentration in sediments.**

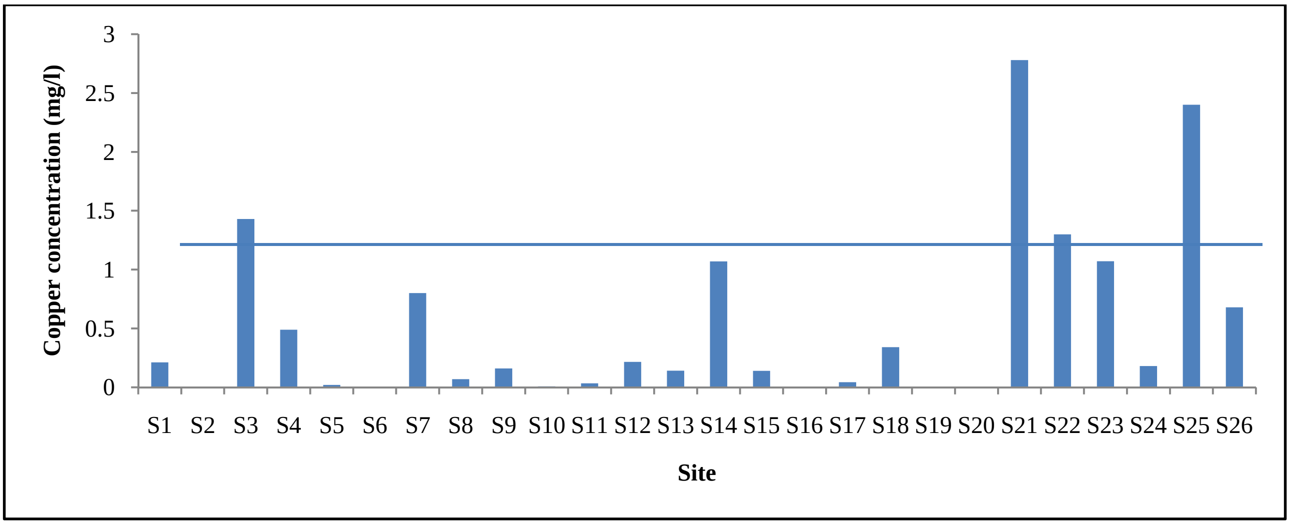

Fig. 18 Copper levels in water.

bridge recorded the highest iron levels of 0.9 mg/L, followed by River Nzoia at Brigadier bridge in Soysambu (0.82 mg/L) (Figs. 16 and 17). The high levels of iron were attributed largely to soil erosion carrying iron minerals to river waters. Intervention measures should include control of soil erosion to reduce the amounts swept into the rivers in the catchment. For drinking water, filtration, ozonation, chlorination and use of water softeners should be taken in consideration to reduce potential health risks associated with consumption of such water.

For sediments, all the sampled rivers had iron content ranging between 3,000-4,000 ppm except at the main source of river Nzoia (Kapolet North water treatment site) which had very little sediment mainly white sands (Fig. 17). This was consistent with the iron content in water at the same site.

All the sampled sites in the catchment recorded high concentrations of copper in water against the acceptable limits of 1.0 mg/L [19] for natural portable waters and 0.05 mg/L [18] for natural domestic water sources and irrigation. The highest concentrations of 2.78 mg/L and 2.4 mg/L were recorded at River Nzoia at Webuye Bridge and River Nzoia at Sigomre Bridge respectively (Fig. 18). The high levels of copper were attributed to high volume of water at the sites and therefore increased carrying capacities mainly erosion. In addition, point-source pollution from industries near Webuye town and farming activities in the surrounding areas are other possible sources. Copper is an essential trace nutrient required in small amounts by humans, plants and animals and therefore mitigating measures are necessary to reduce the high concentrations in the affected areas.

For sediments, Rivers Kiptogot, Mubere, Kaibey/Koitobos and Sabwani recorded high concentrations of copper i.e. 178.52 ppm, 189.59 ppm, 147.84 ppm and 92.47 ppm respectively (Fig. 19). This was attributed to non-point pollution especially from highly intensified agricultural activities in these regions majorly large scale flower and cereals production which use a lot of growth enhancers and herbicides. Copper is moderately soluble in water and binds easily to soil particles and organic matter. The levels of copper in sediments can provide an indication of the level of pollution of the river as the sediments act as permanent or temporary traps for materials present in the river. The effects of copper on aquatic life include fraying of fish gills and reduced olfaction function in fish.

3.7 Electrical Conductivity and pH

The pH values of the sampled rivers were all within acceptable limits [18, 19] for both domestic water

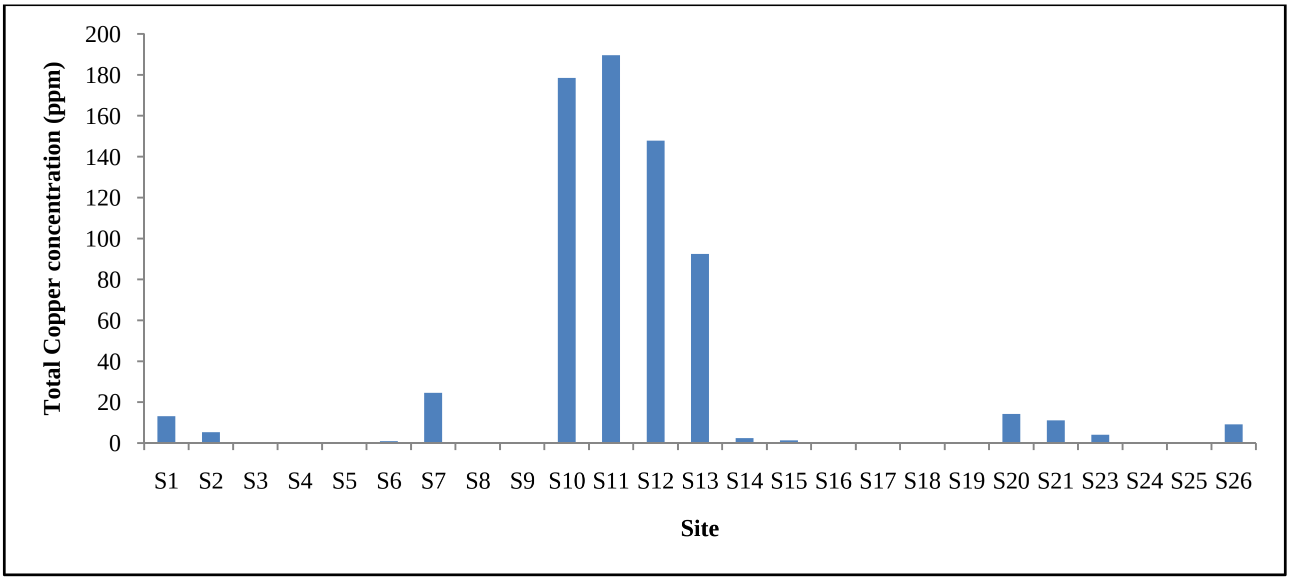

Fig. 19 Total copper levels in sediments.

natural sources and as drinking water before treatment. The same trend was observed for sediments except for River Nzoia at Kapolet Bridge which recorded a low pH of 5.75. The low pH could be attributed to anthropogenic activities mostly pollution from phosphates and nitrate fertilizers as well as the witnessed animal watering points in the sub-catchment. Most aquatic organisms prefer water with pH range of between 6.5 and 8.4. Water with a pH less than 4.8 or greater than 9.2 can be harmful to aquatic life. The electrical conductivity of the river waters was within the acceptable limits (2.5-11.5 mS/m) against maximum acceptable limit of 250 mS/m [19]. This implied that there was a low pollution of ionic salts in the rivers from the catchment. For sediments, there was a correlation between the electrical conductivity and metal cations concentration for copper, zinc and magnesium.

3.8 TDS and TSS

In Kenya, the TDS concentrations in natural portable drinking water should not exceed 1,500 mg/L [19] while water quality standards for both domestic and irrigation water sources should not exceed 1,200 mg/L [18]. All the recorded concentrations of TDS (33-352 mg/L) were below the maximum allowed limits implying that the river water did not have high concentration of dissolved solids.

The volume of the suspended solids in water in all the sub-catchments was within the NEMA (National Environmental Management Authority) water quality acceptable limits of 30 mg/L for domestic and commercial waters in Kenya [18]. The low levels of TSS in water were attributed to the sampling period whereby, it was carried out during the rainy season and river discharge rates were high hence the suspended solids were washed away downstream. However, for drinking water, the TSS levels should not be detected as per the Kenya portable natural water standards [19].

3.9 Hardness

The total hardness concentrations of the sampled rivers ranged from 0.1 mg/L to 5.96 mg/L, against the acceptable limits in Kenya set by KEBS of 600 mg/L for natural portable waters [19]. The results implied that the river waters are soft hence suitable for domestic, agricultural and industrial use. Total water hardness is a measure of dissolved minerals mostly calcium and magnesium in water and is expressed as milligrams per liter (mg/L) of calcium carbonate ($CaCO_3$). Water containing calcium carbonate at concentrations below 60 mg/L is generally considered as soft; 60-120 mg/L, moderately hard; 120-180 mg/L, hard; and more than 180 mg/L, very hard [20].

3.10 Heavy Metals (Mercury, Cadmium, Arsenic, Zinc and Lead)

In this study, the concentrations of mercury, cadmium and arsenic recorded from the Catchment Rivers were below 0.001 mg/L and within acceptable Kenyan limits of natural portable water set by KEBS of 0.001 mg/L and NEMA (0.01 mg/L) for domestic water sources. In addition, the concentrations of these heavy metals were within the limits allowed for both irrigation and recreational uses in the environment [18] in Kenya. These negligible concentrations were attributed to the fact that there were few activities within the sampled sites that released these heavy metals in rivers. The lead concentrations recorded for almost all the rivers (0.001-0.009 mg/L) were within the acceptable limits of 0.05 mg/L [18] domestic water sources and 0.01 mg/L for natural portable waters [19]. Human exposure to lead causes brain damage, mental retardation, lung cancer and even death of unborn babies. These negligible concentrations can be attributed to the fact that there were no or few activities within the catchment that release lead in river waters. In this study, zinc was recorded from all the rivers sampled (0.12-0.9 mg/L) with its values being within the acceptable limits of 1.5 mg/L [18] for domestic water sources. Exposure of zinc to plants may lead to bio-accumulation thus posing health risks along the food chain.

3.11 Water Temperature

Water temperatures in the catchment varied with the altitude of the site and ranged between 16 °C along River Chepkaitit in Kapcherop (2,353 m absl) and 22.9 °C (1,180 m absl) on River Nzoia at Rwambwa Bridge near Lake Victoria. These water temperature variations were majorly attributed to altitude and prevailing weather conditions. In addition, other factors known to influence water temperatures include: shading and ground water influx.

3.12 Fecal and Total Coliforms

In this study, all the sampled sites within the catchment had no fecal bacteria detected except in R. Kipkaren at Kipkaren Town Bridge (47 CFU/100 mL). This could have been caused by the high urban population in Kipkaren town and lack of sewage treatment systems in the urban Centre leading to both human and animal wastes finding its way into the waters. In Kenya, both the fecal and total coliforms should not be present in natural portable drinking water [18].

4. Conclusions

All the rivers in the watersheds forming the River Nzoia catchment contained high levels of iron in water which exceeded permitted levels for drinking without treatment and for domestic uses in the environmental. In addition, the turbidity levels of water were beyond accepted limits set for drinking water and environmental water standards. There was no pollution of water from heavy metals (mercury, cadmium and lead). River Nzoia near Webuye town and Sigomre bridge were the most polluted waters with levels of nitrates, iron, copper, chromium, BOD and COD exceeding the accepted limits in the environment. For sediments, the contents of copper, magnesium and iron were high in the upper catchment of river Nzoia (foot slopes of Mt. Elgon). The levels of nitrates and phosphates in the sediments were high in the lower parts of the catchment. A wide range of interventions were proposed to manage point or non-point pollution sources which included land and soil conservation measures to reduce erosion and sedimentation, precise fertilization, proper sewage treatment and disposal, proper industrial effluent treatment among others. For point source pollution, the interventions especially for high BOD and COD levels in water should be aimed at monitoring possible pollution sources in the study area i.e. from nearby industrial effluent discharge sites, sewage treatment systems and horticultural farms. To reduce or manage high BOD/COD values, proper design of waste water and sewage treatment plants should be done especially aeration.

To reduce high turbidity, land and soil conservation strategies to control soil erosion at the sub-catchment levels are recommended. In addition, organic farming should be encouraged in the region to reduce use of chemicals (pesticides) which pollute rivers and conservation agriculture practices like minimum/zero tillage, crop rotation etc. to help conserve the soil and the environment.

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